Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

ALASKA OREGON WASHINGTON
PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION

USDA FOREST SERVICE RESEARCH NOTE

PNW-139 January 1971

COLLAPSE OF AN OUTBREAK POPULATION OF THE DOUGLAS-FIR TUSSOCK MOTH, *HEMEROCAMPA PSEUDOTSUGATA* (LEPIDOPTERA: LYMANTRIIDAE)

FOREST AND RANGE
EXPERIMENT STATION
JUL 12 1971
STATION LIBRARY COPY

by

Richard R. Mason, *Insect Ecologist*

and

C. G. Thompson, *Principal Entomologist*

Keywords: Hemerocampa pseudotsugata, Douglas-fir tussock moth, Abies concolor, virus diseases (insects), forest insects, insect populations, Modoc National Forest, Calif.

ABSTRACT

An outbreak population of the Douglas-fir tussock moth on white fir was studied during the summer of its collapse. Survivorship curves and a partial life table were prepared which illustrate the pattern of the population decline. The major cause of collapse was a natural epizootic of virus disease in the larval population. However, a late spring frost which destroyed much of the preferred food of early-instar larvae may have also contributed significantly. Density of early-instar larvae declined more sharply in heavy than in light population areas which suggests that larval survival was partially density-dependent.

INTRODUCTION

Outbreaks of the Douglas-fir tussock moth, *Hemerocampa pseudotsugata* McD., occur periodically in the true fir, *Abies* spp., and Douglas-fir, *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, forest in western North America. Tussock moth populations build up inconspicuously over a period of years until a defoliation threshold is reached when they may suddenly cause unexpected extensive damage. When a damaging outbreak does occur, the tussock moth population may remain at a level causing heavy defoliation for from 1 to 3 years, after which the population usually abruptly declines. Most tussock moth infestations that are allowed to run their natural course seem to be terminated eventually by an epizootic of nucleopolyhedrosis virus (Hughes and Addison 1970).[1] Unfortunately, outbreaks seldom end before they have caused considerable tree damage (Wickman 1963).

In 1965, an outbreak of tussock moth on white fir, *Abies concolor* (Gord. and Glend.) Lindl. was detected over a 450-acre area in Modoc County in northern California. In 1966, the larval population was studied from eclosion in early June until August when virtually all larvae vanished just prior to pupation. For 2 years thereafter, no larvae were recovered from sampling in the area.

In this paper, population data are presented which document the natural decline of larvae in this outbreak. An analysis is also made of some of the factors which seemed to influence the collapse.

METHODS

Description of the Area and Study Points

The outbreak was located in the general boundaries of the Modoc National Forest in California. The forest type was predominantly an overstory of old-growth ponderosa pine, *Pinus ponderosa* Laws., in association with a heavy understory of white fir.

Eight study points were established in the infestation (fig. 1). Five were in the center zone of heaviest defoliation (more than 30 percent) and three in transition zones of lesser defoliation (less than 30 percent). Ten white fir trees were selected at each point from which successive samples were taken during the study period.

Population Sampling

The larval population in the vicinity of each point was evaluated biweekly during June and July 1966 by estimating the mean density of larvae per thousand square inches of branch area on the 10 sample trees. Density was estimated by tallying the number of larvae on six 17-inch twigs taken systematically from three crown levels of each sample tree at the point. Counts of larvae on the twigs were weighted according to the distribution of foliage in the tree. The standard error of the mean density of larvae at each point was within 20 percent. Methods for sampling and evaluating tussock moth populations have been reported in more detail (Mason 1970).

Parasites and Disease

Mortality of larvae from parasites and disease was determined for the infestation as a whole from biweekly collections of larvae at 25 sampling stations.

---

[1] *B. E. Wickman, G. C. Trostle, and P. E. Buffam. Douglas-fir tussock moth. Forest Pest Leafl. 86 (rev.). USDA Forest Serv. In press.*

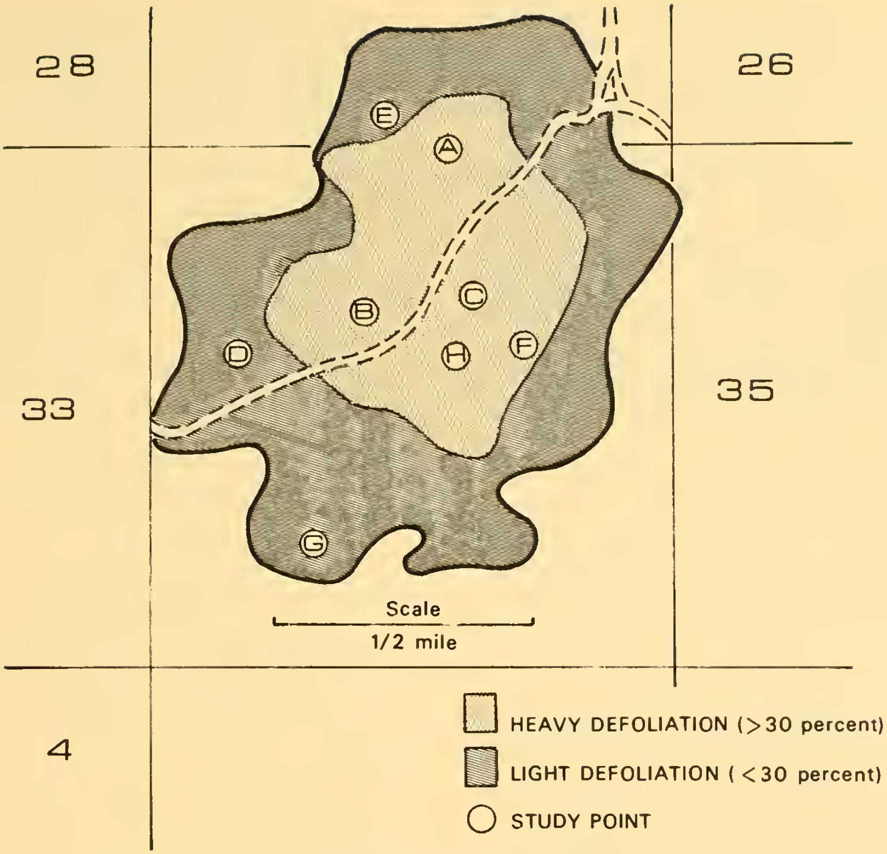
28
26
E
A
33
35
D
B
C
H
F
G
Scale
1/2 mile
4
HEAVY DEFOLIATION (>30 percent)
LIGHT DEFOLIATION (<30 percent)
STUDY POINT

Figure 1.--*Map of 1966 outbreak of the Douglas-fir tussock moth, Modoc County, Calif.*

Collected larvae were reared singly under aseptic conditions at the Forestry Sciences Laboratory at Corvallis, Oreg. Cause of death was determined in each instance. Although the data from the laboratory rearings are believed to represent a reasonably close approximation of the prevalence of polyhedrosis in the field, the differences in environmental and nutritional conditions might be expected to produce some differences from the actual field prevalence.

RESULTS

Survivorship Curves and Partial Life Table

Two survivorship curves were constructed for larvae by pooling separately the data from points in the heavily infested area and the data from the points in the lightly infested area. The decline of the mean density of larvae at points in the two areas through the summer is shown in figure 2. In general, the distribution of survivorship in both areas had a concave form, implying that mortality rate was relatively constant for all age groups of larvae. The logarithm of larval density in each area plotted over time would be roughly a diagonal straight line where mortality is relatively constant for all ages of larvae. This would be the Type II form of survivorship described by Deevey (1947).

Study points in the area of heaviest defoliation showed a particularly sharp decline in number of first-instar larvae. As a result, larval density at points in both the heavy and light areas approached a similar density level by the third instar. Thereafter, population decline occurred at a more constant rate at all points. Field sampling was discontinued after July 25, 1966, when the few

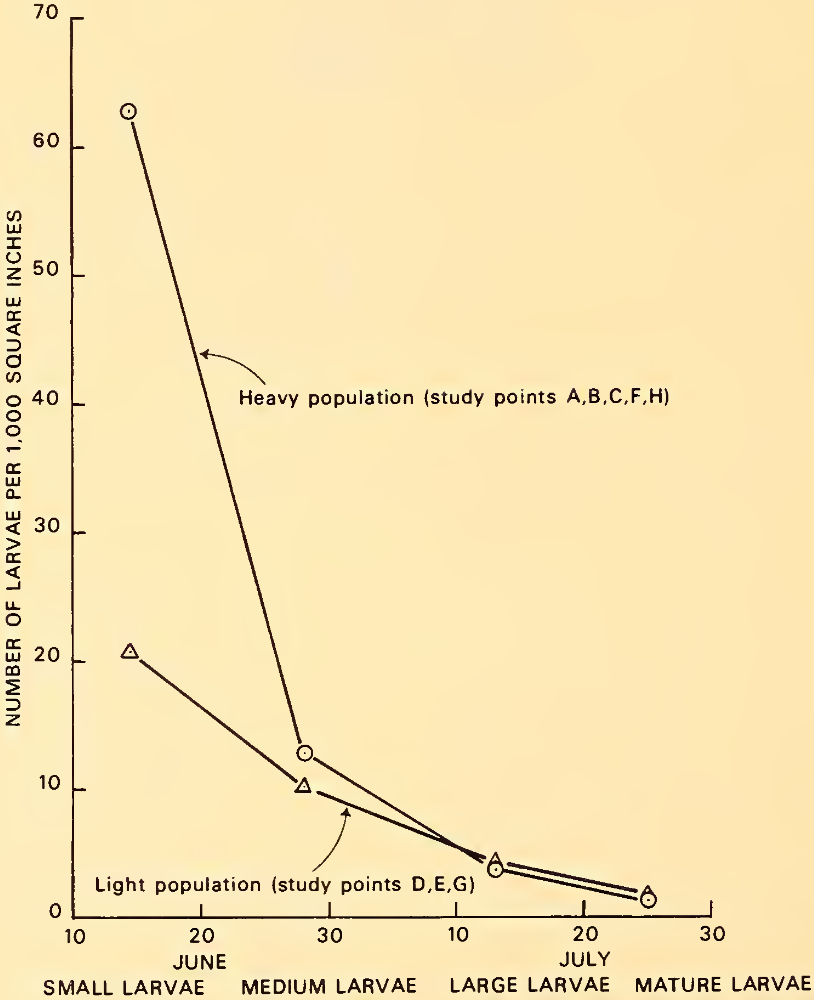

Figure 2.--*Survival of tussock moth larvae in areas of two different population intensities during 1966.*

remaining larvae reached maturity. However, it is safe to assume that all density values must have dropped to near zero by early August because no pupae could be found after considerable searching.

A general life table has been prepared for eggs and larvae by pooling data from all of the study points (table 1). This was constructed after Morris and Miller's (1954) format. It is a useful way of illustrating average decline in the outbreak in relation to the mortality factors responsible. Since an accurate estimate of number of eggs was not available, a minimum egg density value for the table was calculated by adding mortality that occurred during the first age interval to the first larval sample.

Over the course of the entire larval stage, virus disease accounted for 41-percent mortality and was the major cause of death in the population. Egg and larval parasites combined accounted for another 23-percent mortality. A relatively large proportion (34 percent) of the loss was unaccountable in the life table.

A late spring frost about the time of egg hatch killed much of the tender new foliage on white fir so that there was a scarcity of the preferred food of young larvae. This probably caused starvation of some early-instar larvae (Mason and Baxter 1970). It also seemed to stimulate excessive larval dispersal by wandering or ballooning on silk threads; likewise, this may have increased the probability of predation. Early in the cycle, these losses undoubtedly were responsible for much of the unaccountable mortality which, at that time, exceeded the loss caused by virus disease. However, later in the cycle they accounted for proportionately less mortality as the incidence of virus increased.

The final density of mature larvae was probably considerably lower than the calculated value of 1.0 in the table because no pupae were observed in the field. As the season progressed, fewer larvae were available in the field for sampling virus disease; therefore, the estimate of disease incidence became less reliable toward the end of the cycle and could easily have been underestimated.

Two species of ichneumonid parasites were responsible for most of the larval parasitism recorded. Their impact on the population could have been considerably greater than indicated by the life table because some female adults in this family may also feed on other larvae before ovipositing. This would be a form of predation by the adult parasite that could not be determined from larval rearings.

Analysis of Survival

Study points in the infestation were especially useful when they were treated as replicates and each point analyzed as a separate population. For the most part it was realistic to assume that the points contained relatively independent populations during the larval stage. Regression analyses were then performed which revealed certain processes involved during the decline of the outbreak.

Table 1.--*Partial life table for 1966 generation of Douglas-fir tussock moth at Corral Creek, California*

Sample date	Age interval (x)	Number alive at start of x (per 1,000 square inch) (l_x)	Factors responsible for d_x (d_xF)	Number dying during x (d_x)	d_x as percentage of l_x ($100q_x$)
May 24	Eggs	[1](61.9)	Egg parasites	7.4	12
			Virus disease of 1st-instar larvae	6.2	10
			Larval parasites	1.2	2
			Subtotal	14.8	24
June 12-17	Small larvae (1st instar)	47.1	Virus disease	13.2	28
			Larval parasites	4.2	9
			Unaccountable	18.0	38
			Subtotal	35.4	75
June 27-30	Medium larvae (1st, 2d, and 3d instars)	11.7	Virus disease	4.6	39
			Larval parasites	1.0	9
			Unaccountable	2.2	19
			Subtotal	7.8	67
July 11-15	Large larvae (3d, 4th, and 5th instars)	3.9	Virus disease	1.4	35
			Larval parasites	.3	9
			Unaccountable	.9	23
			Subtotal	2.6	67
July 25-27	Mature larvae (5th and 6th instars)	1.3	Virus disease	.2	15
			Larval parasites	.1	8
		[1](1.0)			
			Summary of mortality:		
			Virus disease	25.6	41.3
			Egg parasites	7.4	12.0
			Larval parasites	6.8	11.0
			Unaccountable	21.1	34.1
			Total	60.9	98.4

---

[1] Values calculated from mortality data.

Survival of larval populations from one sampling period to the next was investigated using the expression $S = S_S \times S_M \times S_L$ where S is the proportion of the larval population surviving to mature larvae and S_S, S_M, and S_L are age interval survival estimates of small, medium, and large larvae, respectively. Survival estimates were calculated at each study point from the mean density values of the four larval samplings ($N_1 \ldots N_4$) by $S_S = N_2/N_1$, $S_M = N_3/N_2$, and $S_L = N_4/N_3$. These estimates are given in table 2.

The analysis made was similar to that described by Watt (1963) and Morris (1963) but was modified because of incomplete generation data. Survival data were first transformed to logarithms to improve linearity and stabilize variance. Then a series of simple linear regressions were calculated to determine which of the age interval survivals (S_S, S_M, S_L) contributed most to variation in total larval survival.

The results in table 3 show that survival of small and large larvae was each significantly related to total survival. Of these, survival of small larvae accounted for most of the variation in overall survival (74 percent). These correlations are useful as a tool to detect the stage of development during which mortality factors are most influential in establishing the form of population decline.

As survival of small larvae seemed to have the most influence on the final value of larval

Table 2.--*Initial density* (N_1), *age interval survival* (S_S, S_M, S_L), *and total survival to mature larvae* (S) *at each study point*

Study point	N_1	S_S	S_M	S_L	S
	Number per 1,000 sq. in.	- - - - - - -	- - -*Proportion*	- - - - - - -	
C	76.9	0.077	0.169	0.200	0.003
F	64.7	.187	.256	.516	.025
A	64.4	.562	.276	.320	.050
B	58.0	.043	.560	.143	.003
H	50.7	.136	.391	.111	.006
E	27.7	.520	.583	.357	.108
D	20.4	.588	.210	.600	.074
G	13.8	.261	.556	.250	.036
Mean	47.1	.297	.375	.325	.038

Table 3.--*Regression statistics of larval survival*

Dependent variable	Independent variable	r	r^2
S	S_S	[1]0.860	0.740
S	S_M	-.236	.056
S	S_L	[1].784	.615

[1] Significant at the .01 level.

survival, this stage should be examined further. From figure 2 it can be seen that the decline of mean density of small larvae was sharpest at the study points in the area of the heaviest population. A negative relationship seems to exist when small larval survival is plotted over initial mean density and a logarithmic curve fitted to the data (fig. 3). Although too few observations were available to establish a significant correlation, the graphical relationship shows that mortality factors were usually more active at high than at low population density. Therefore, survival of small larvae was probably density-dependent. This is not surprising when the major causes of mortality at that stage are considered (table 1). Starvation, loss from dispersal, and virus disease would all tend to be more pronounced at high than at low population densities. Later in the summer, as overall density of larvae declined and as virus disease spread through the entire infestation, there was no detectable relationship between density and survival.

CONCLUSIONS AND DISCUSSION

The collapse of the outbreak seemed to be due largely to the extensive mortality from virus disease. Although a shortage of food occurred which may have caused some starvation and exceptional dispersal losses of young larvae, the overriding factor in the collapse was disease.

For the infestation as a whole, the average rate of virus mortality was relatively constant in all larval stages. However, at different study points the variation in decline of early-instar larvae appeared density-dependent. Circumstantial evidence indicates that this variation could have been due to differential incidence and spread of virus early in the summer. Added stress to the population caused by food shortage could also have influenced the course of the epizootic.

The pattern of decline in this outbreak will be useful in interpreting other tussock moth infestations. Current studies in

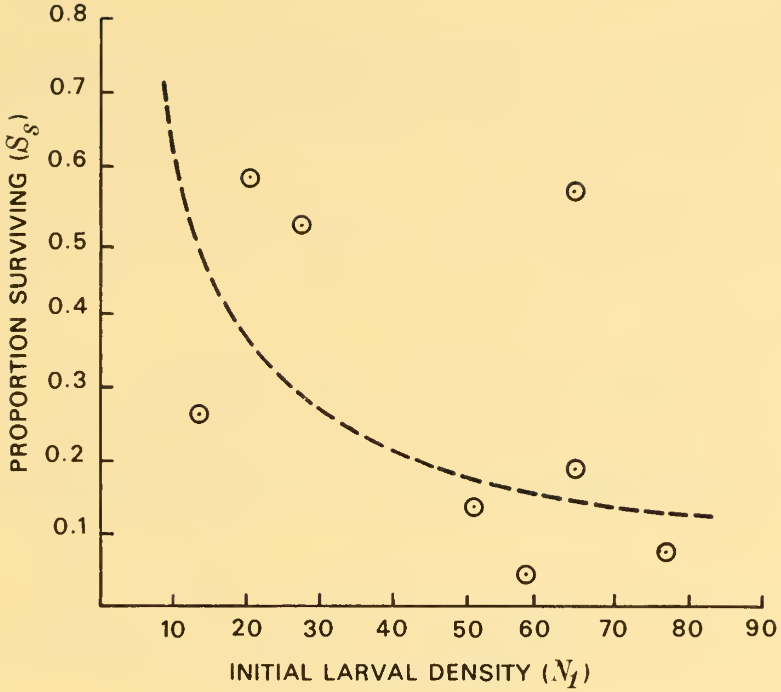

Figure 3.--*Relationship between survival of small larvae* (S_s) *and initial larval density* (N_1). *Curve is fitted from the logarithmic linear relationship.*

tussock moth population dynamics indicate that survivorship of larvae could be a key to distinguishing infestation trend. For example, larval survival during the declining stage of this outbreak averaged 3.8 percent (table 2); however, survival in disease-free populations that are increasing has averaged more than 20 percent. Eventually, it may be possible to use such survivorship data in research as an index to increasing or decreasing populations and for evaluation of forest conditions in relation to tussock moth outbreaks.

LITERATURE CITED

Deevey, E. S.
1947. Life tables for natural populations of animals. Quart. Rev. Biol. 22: 283-314.

Hughes, Kenneth M., and R. B. Addison.
1970. Two nuclear polyhedrosis viruses of the Douglas-fir tussock moth. J. Invertebr. Pathol. 16: 196-204.

Mason, Richard R.
1970. Development of sampling methods for the Douglas-fir tussock moth *Hemerocampa pseudotsugata* (Lepidoptera: Lymantriidae). Can. Entomol. 102: 836-845, illus.

__________ and Jerrold W. Baxter.
1970. Food preference in a natural population of the Douglas-fir tussock moth. J. Econ. Entomol. 63: 1257-1259.

Morris, R. F. (ed.)
1963. The dynamics of epidemic spruce budworm (*Choristoneura fumiferana*) populations. Mem. Entomol. Soc. Can. 31, 332 p.

__________ and C. A. Miller.
1954. The development of life tables for the spruce budworm. Can. J. Zool. 32: 283-301.

Watt, Kenneth E. F.
1963. Mathematical population models for five agricultural crop pests. Mem. Entomol. Soc. Can. 32: 83-91.

Wickman, Boyd E.
1963. Mortality and growth reduction of white fir following defoliation by the Douglas-fir tussock moth. Pac. Southwest Forest & Range Exp. Sta. USDA Forest Serv. Res. Pap. PSW-7, 15 p., illus.

ACKNOWLEDGMENTS

Special appreciation is due Weyerhaeuser Company for its cooperation in reserving the outbreak for study. Thanks are also due T. C. Tigner, biological technician, for valuable assistance in the field.

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research will be made available promptly. Project headquarters are at:

College, Alaska
Juneau, Alaska
Bend, Oregon
Corvallis, Oregon
La Grande, Oregon
Portland, Oregon
Roseburg, Oregon
Olympia, Washington
Seattle, Washington
Wenatchee, Washington

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.